International Journal of Innovative Research in Computer and Communication Engineering

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906222 |

DESIGN AND ANALYSIS OF NOVEL MICROSTRIP PATCH ANTENNA ON PHOTONIC CRYSTAL FOR HIGH SPEED THz APPLICATIONS

G. Naveen Kumar, M. Chakradhar, P.Bala Venkata Sai Mahesh, K. Gopi, N. Veda Praneeth.

Department of Electronics and Communication Engineering, Vasireddy Venkatadri Institute of Technology, Nambur,

Jawaharlal Nehru Technological University, Kakinada, Andhra Pradesh, India.

ABSTRACT: Present generation communication needs low value, negligible weight, low profile, high gain and superior antenna to execute the demand of the longerterm and realization. This requires a high gain novel microstrip patch antenna design is planned, supported the photonic crystal for THz (THz) spectral band applications. This antenna is mounted on polyimide substrate that employs Photonic Band Gap (PBG) crystal and therefore the Gain of 7.67dB,Directivity 8.7 dB and VSWR on the point of unity at resonant frequency of 0.631 THz. The planned antenna model is compared with polyimide substrate structure based mostly microstrip patch antenna and the performance of patch antenna is limited due to surface leaky waves, therefore designing of the patch antenna is enhanced by implanting photonic crystals in the thick dielectric substrate. Here the patch is designed with graphene material and analyzed the radiation characteristics. Moreover, the performance of designed antenna is investigated with totally different PBG cylindrical distance, PBG hole radius, curvature radius of patch and substrate heights. The projected style antenna encompasses a information measure of 33.25 GHz and −10 dB electric resistance with operational frequency vary variable from 0.61 THz to 0.65THz, thence it may be utilised for detection of explosive and material characterization applications.

KEYWORDS: Microstrip patch antenna, CST, PBG, Polyimide. THz band, Radiation characteristic

I.INTRODUCTION

During the last decade, vital advancement within the communicationsystem at THz spectrum and emerged into a lively spaceof analysis. The terahertz is outlined as a region of spectrumbetween microwave and infrared regions, that ranges within the frequencyvarying from 0.1 to 10 THz. This waveband guarantees aremarkable application in high-speed communications up to ten Gigabits per second (Gbps) [1]. The utilization of THz systems isgaining quality due to the advantages of the high frequency region as miniaturized in size, spatial radial asymmetry,high speed communication and broader bandwidths.[2] Thedevelopment of the THz elements leads towards the fourth and fifth generation of communication innext decade. Earlier, the elements were restricted to develop with the nonplanar structures like rectangular waveguides and concentrical lines just for lowloss, highpower handling capability. additional or less underthe fragrance of THz frequency regime, the evolution within the existing and new application space such asnation security, spectrometry, sensing, microwave radar imaging,detecting explosive and art conservation is ongoing.In this context of advance THz systems, antennaplays a major role when deciding regarding the qualityof the system [3-5].THz frequency willsuffers high attenuation path and getting loss in the presence of lowattenuation windows [6].Hence desire of high Gain antennasfor the detection of explosives via spectroscopic techniques is a primary issue for present technology. We have various antennas in the THz region, some of them are: Yagi-Uda [7], log-periodic [8], bow tie [9], on-chip antenna [10], and substrate integrated waveguides [11].

In this paper the main role is to build photonic band gap structure for preventing the flow of certain bands of frequencies. This idea of “photonic crystal (PC)” was initially explored byYablonovitch [12] and John [13] in 1987. Inaddition to this the PBG structures have been shown to suppresssurface waves whereas they would be present on normalground planes. Generally, PBG structures are periodic innature. Photonic crystals will be achieved by implantingthe different materials such as metallic, dielectric andferromagnetic in the dielectric substrate materials. Mainly PBGs are oftwo types i.e. 3D and 2D, in which 3-dimensional pho-tonic crystals are difficult to realize. And the 2-dimensionalphotonic crystals are easy to embed in a dielectricsubstrate. Gonzalo et al. [14]The idea of this paper is to demonstrate a novel design of antennafor terahertz frequencies and performance enhancementof the proposed antenna by implanting cylindrical shapephotonic crystals in the dielectric substrate layer.

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906222 |

II. ANTENNA CONFIGURATION

The miniature and high performance is thepresent issue in the field of wireless communication. Miniaturization directly meets the need of size reductionof the device that also reduces the energy required by the device. This high performance controls the problems of gain,bandwidth and loss in dielectrics. during this Section cylindrical shape microstrip patch antenna with implantation of photonic crystals within the substrate layer has to be designed [15-16].

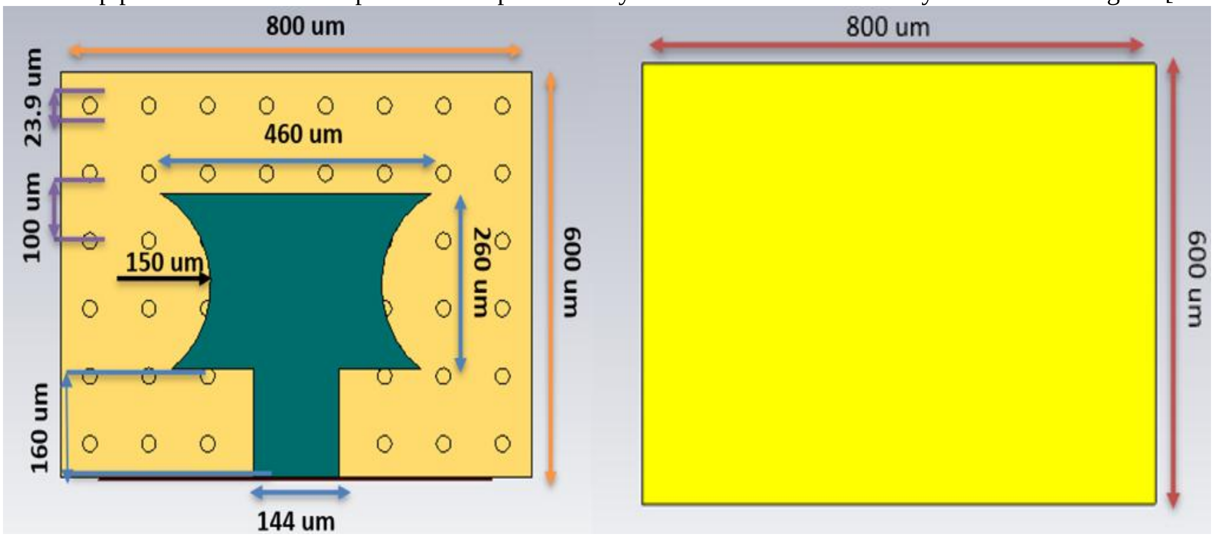

Fig1: Front and Back view of proposed design.

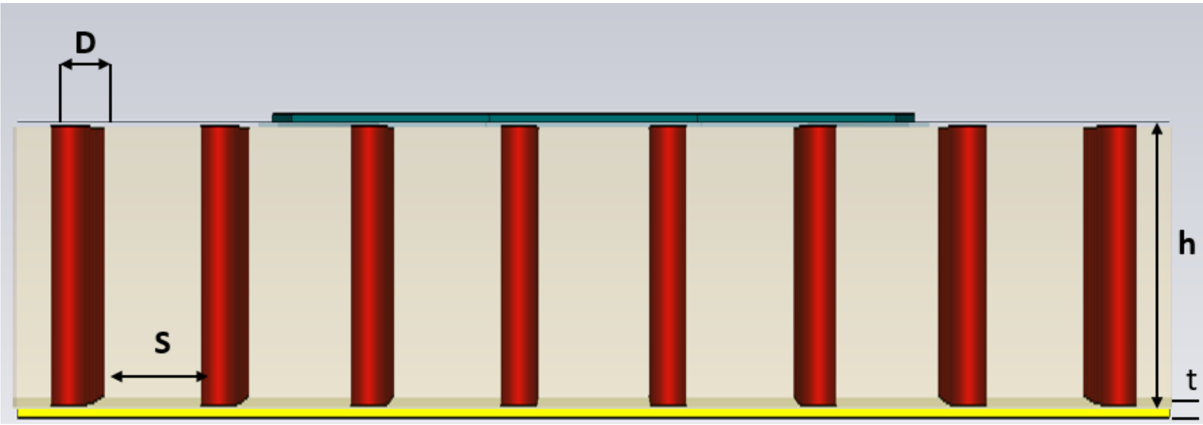

Fig 2: 3D structure of cylindrical implantation in dielectric substrate

The microstrip patch antenna is placed over the ground plane and in between dielectric substrate is placed whereas it exhibits photonic band gaps with cylindrical crystals. Fig 1 denotes the proposed front and back view design it consists measurements of the design. Fig 2 denotes the 3D implantation of cylindrical photonic band gaps in the dielectric substrate.

Let, w_P and L_P be the width and length of the patch respectively and the dimensions of the patch will be calculated by

$$w_P = \frac{(2M+1)}{\sqrt{\varepsilon_\gamma}} X \frac{\lambda_0}{2} \qquad (1)$$

$$L_P = \frac{(2N+1)}{\sqrt{\varepsilon_{eff}}} X \left(\frac{\lambda}{2}\right) - 2X\Delta L \qquad (2)$$

Where, M and N are non-negative integers (M=N=1);
λ_0 and λ are free space and operating wavelengths;
ε_γ is the relative dielectric constant;

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906222 |

ε_{eff} is the effective dielectric constant;
and, ΔL is the patch length extension due to Fringing field effect
Now,w_f and L_f are the width and length of the feed and z_a is input impedance of the antenna. Here z_a is matched with 50Ω impedance through this feeding line then the characteristic impedance is $z_0 = 50Xz_a$

$$z_a = \frac{11.96\lambda_0}{w_f} \quad (3)$$

$$w_f = \frac{7.475h}{\exp(x)} - 1.25t \quad (4)$$

Where,$x = \frac{z_0\sqrt{\varepsilon_\gamma + 1}}{87}$, and h and t are hight of the substrate and thickness of the patch respectively and the dimensions of the substrate and ground will be calculated by

$$w_s = w_g = w_p + 2xL_f \quad (5)$$

$$L_s = L_g = L_p + 2xL_f \quad (6)$$

Where, w_s,w_g are the width L_s,L_g are the length of substrate and ground respectively.

For the need of size reduction in the patch we have to cut the side faces in curved structure by circular cutting with cylinder this creates the improvement of performance of antenna and the other hand PBG structure is created on the polyimide substrate by implanting the periodic arrangement of circular cylindrical with diameter (D) and radius r. The distance between each cylinder is about 100 um that is “S”. The dimensions of the substrate is 800 um x 600 um and hight is 63.7 um, radius of the cylinder is 11.95 um, width of the radiating patch is 460 um a curvature radius of 75 um and the microstrip feed line measurements are 144 um x 160 um to get 50 Ω impedance. The thickness of the patch and ground is 7 um which it was made up by copper and graphene material respectively, and the silver material is used for the microstrip feeding line. All this proposed design will be simulated in CST microwave studio tool.

International Journal of Innovative Research in Computer and Communication Engineering

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906222 |

III.SIMULATED RESULTS AND DISCUSSION

This THz frequency band antenna plays an important role in the ultra-broadband and secured transferring of data in wireless and satellite communication systems. The radiation characteristics of the proposed antenna is designed and observed in the frequency range varying from 0.6 to 0.7 THz, and the performance is measured and investigated in the form of Gain (dB), Directivity (dBi), Return loss (S1,1), VSWR, Z-Parameters and Radiation Efficiency (%).

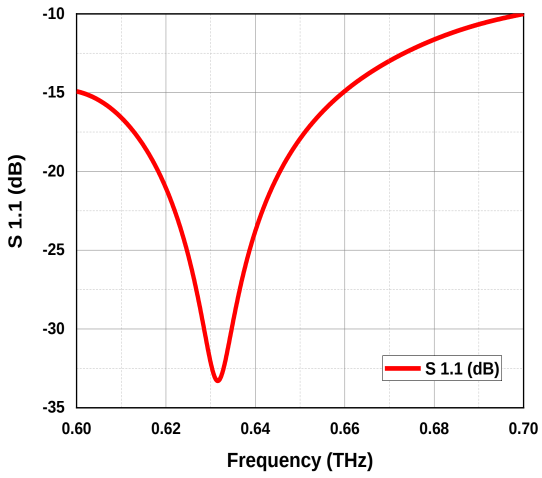

Fig 3: Return Loss performance (S 1,1 (dB))

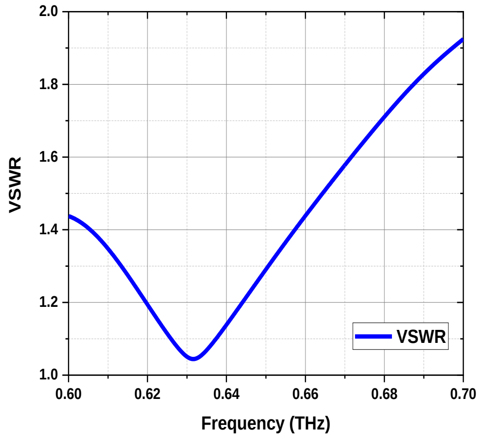

Fig 4: VSWR performance characteristics

Here we clearly observed in Fig. 3 that the PBG antenna offers resonantfrequencies of 0.631 THz with return loss values (S11≤ −10 dB) of−33.28 dB in the frequency band of 0.615–0.651 THz.Fig. 4 shows the impact of PBG in Voltage Standing Wave Ratio(VSWR) shown in blue solid curve. The value of VSWR is 1.04 for the proposed antenna.

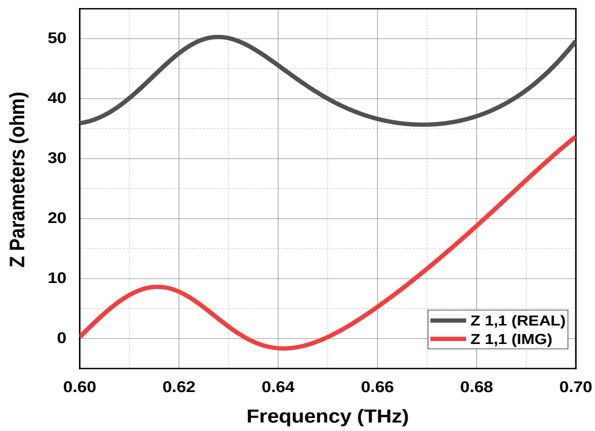

Fig 5: Z-Parameter characteristics of proposed THz antenna.

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906222 |

Inputimpedance is also one of the significant input characteristics of antenna which demonstrates the impedancematching between the input signal and the feedline. Ifthe impedance is matched closely to the 50 , it is saidto be perfectly matched. Here we get about 50.2 which is near to the matched one.

Fig 7: Directivity versus operating frequency

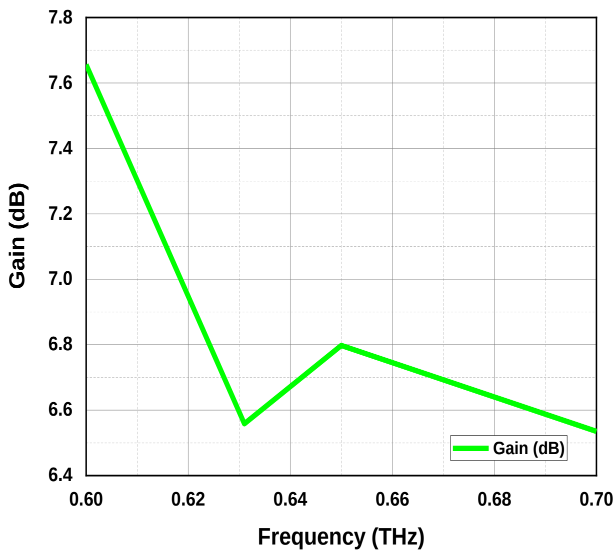

Fig 6: Gain versus operating frequency

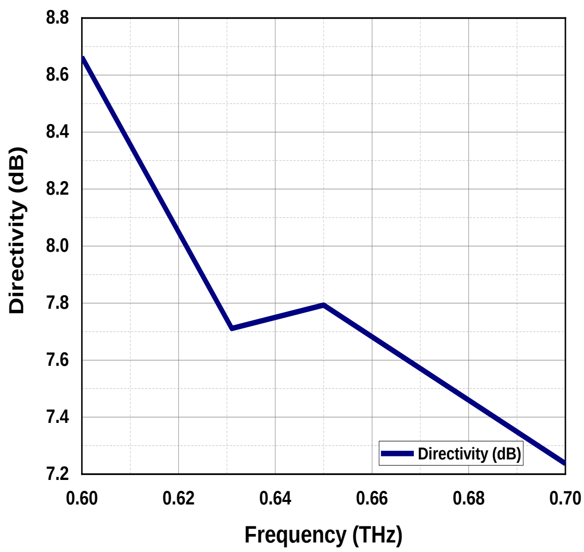

Fig 7: Directivity versus operating frequency

The gain versus all operating frequencies plot is presented in Fig. 6 for verification of the proposed terahertz antenna It is observed from Fig. 6 that proposed antenna exhibits positive gain value for the frequencies range between 0.6–0.7 THz. The maxi-mum gain achieved throughout the main frequency is 7.6 dB which shows good quality of gain value achieved by antenna.Fig. 7 represents another output performance parameter of proposed antenna which tells us about the directionality of the designed antenna i.e. directivity. It is very much obvious from Fig. 7 that the proposed terahertz antenna is directional in the respective frequency band of 0.6–0.7 THz.

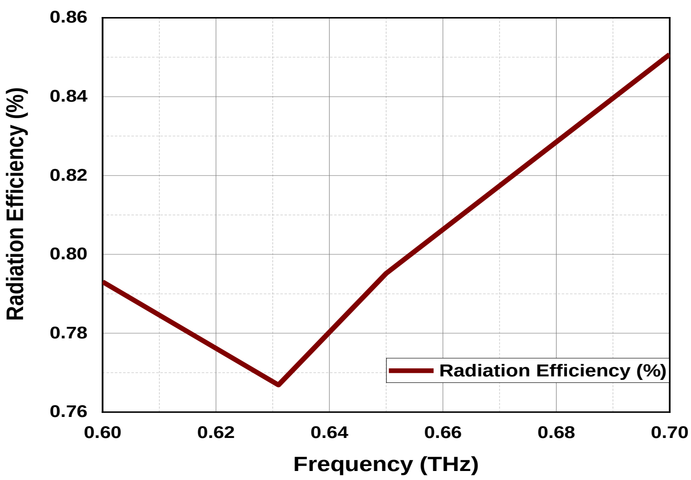

Fig 8: Radiation Efficiency of the proposed THz antenna

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906222 |

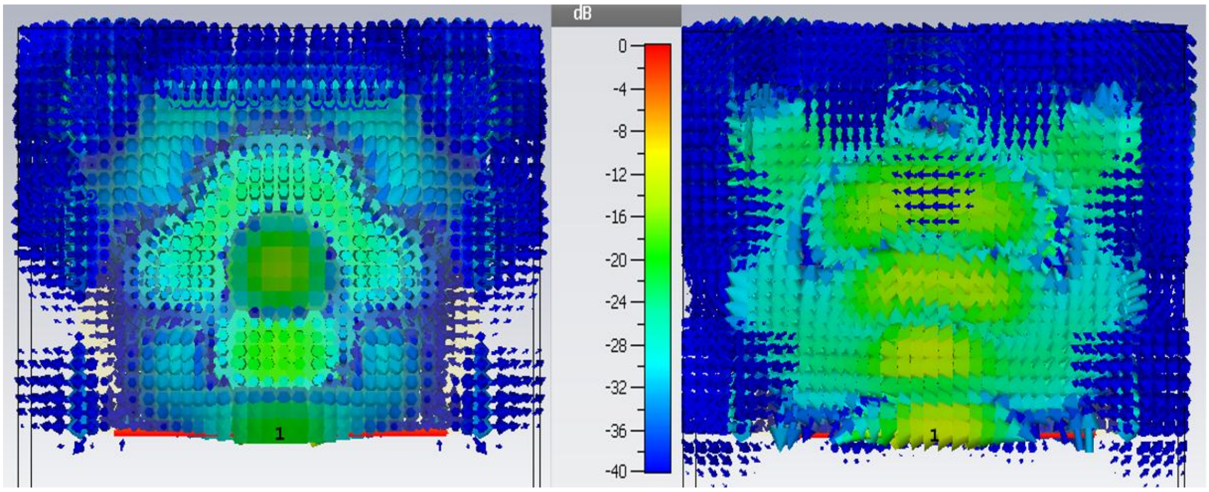

Fig 9: E-Field and H-Field Distribution of the proposed THz antenna

The efficiency of an antenna is defined as the ratio of power radiated in all directions to the total input power supplied to its terminals. In Fig 8. We observed that the Radiation efficiency is occurred more than 80% which shows the better performance of the antenna and in Fig 9. we observe the both electric field and magnetic field distributions of the front plane which is in the range – 16 to – 36 as per the dBmax range. The maximum electric field is through the patch area and at along the edges of substrate it was lowand also the magnetic field distribution is maximum at microstrip feeding and throughout the patch and it was low at the edges of substrate.

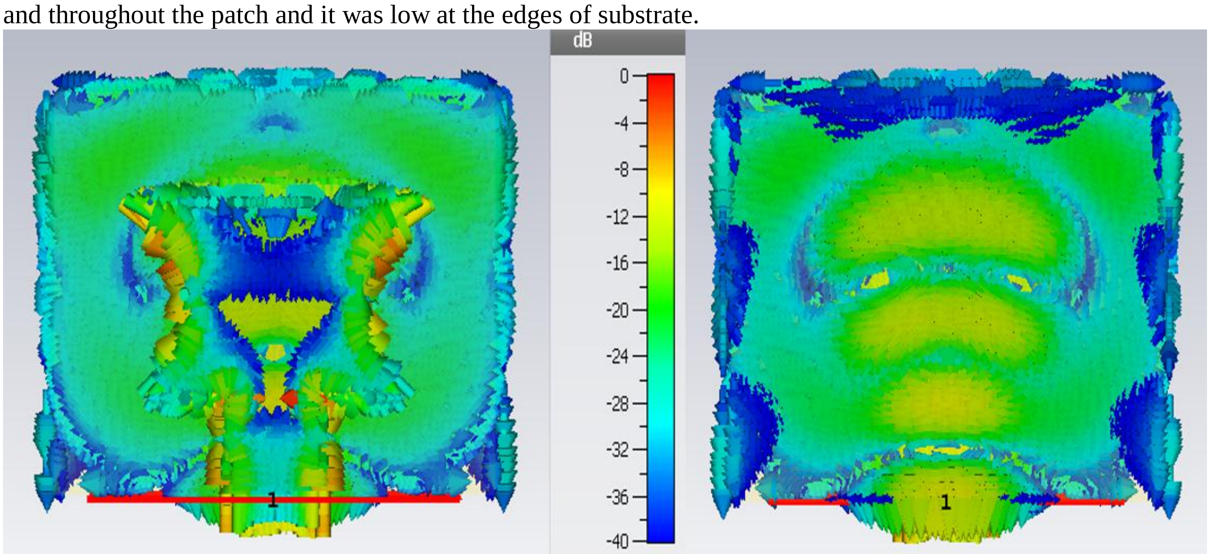

Fig 10: Surface current Distribution to the excited front and back plane of THz antenna

The first one is surface current distribution in excited front plane and second one is current distribution in excited ground planeAnd also here The average current density is shown in different colours. We can see the average currentdistribution on the surface of the antenna. As we can observe the current is in the range of -12 to-28 on the top edge, it is almost maximum at the centre and it is minimum at the edge of the feedline denotes the flow of surface current Distribution.

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906222 |

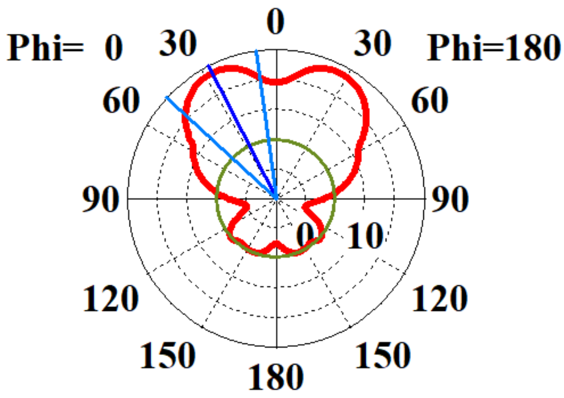

Fig 11: E-Field Radiation Pattern (XY plane)

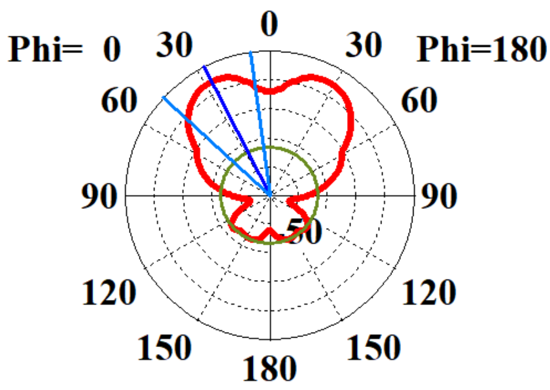

Fig 12:H-Field Radiation Pattern (YZ plane)

The 2-D radiation patterns at different resonant frequencies i.e. 0.6 to0.7 THz are measured as shown in Fig. 11. and Fig 12representsthe gain radiated in elevation plane (Y–Z planes) andazimuthal plane (X–Y planes). Through the study ofradiation characteristics it is observed that the proposed antenna is radiating more in the phi (X–Y planes)direction and less in the theta (Y–Z planes) direction.Normally, the radiation characteristics are determined inthe far field region as a function of co-ordinates and itcan also be classified in terms of power pattern or fieldpattern.
The wavelength (λ) supported by the proposedantenna is in μ meter This antenna exhibits miniaturizedstructure as size of the antenna is proportional to wave-length, hence it is confirmed that the proposed antennawill consume very less power while functioning as transmitter or receiver. If wireless devices like sensors aredeveloped to function in the terahertz frequency regionthen issues of high data rate and less power consumption can easily be resolved.

IV.CONCLUSION

The design of Photonic Band Gap substrate structure with novel microstrip patch antenna have been studied and compared the design characteristic performance.Further, the effects of the photonic crystal along with different curvature radius of patch and height of substrate structure have been observed.This antenna is proposed for terahertz highspeed applications such as THz radar communication, Imaging and high speed scanning systems.The effects of variation in the substrate height on the return loss, percentage bandwidth and gain have also been observed.It has been concluded that with increase in the substrate height, the minimum return loss and impedance bandwidth of antenna decreases significantly.The proposed antenna is acquired the operating frequency 0.6–0.7 THz, which act as the peak absorption frequency and unique spectral signature.Hence, the projected microstrip patch antenna suitably employed to the application for detection of explosive and material characterization.

REFERENCES

[1] S. Koenig, et al., Wireless sub-THz communication system with high data rate, Nat.Photon. 7.12 (2013) 977.
[2] K. Solbach, R. Schneider, Review of antenna technology formillimeter-wave automotive sensors, in: Proceedings of EuropeanMicrowave Conference, October 1999, pp. 139–142.
[3] M. Naftaly, et al., Terahertz transmissionspectroscopy of nonpolar materials andrelationship with composition and properties, Int. J. Infrared Millimet. Waves 26.1(2005) 55–64.
[4] Jun-ichi Nishizawa, et al., THz imaging of nucleobases and cancerous tissue using aGaP THz-wave generator, Optic Commun. 244.1–6 (2005) 469–474.
[5] Joo-Hiuk Son, Terahertz electromagnetic interactions with biological matter andtheir applications, J. Appl. Phys. 105.10 (2009) 102033.
[6] Dwight L. Woolard, James O. Jensen, R. Jennifer Hwu, Terahertz Science andTechnology for Military and Security Applications vol. 46, world scientific, 2007.
[7] Kyungho Han, et al., Terahertz Yagi-Uda antenna for high input resistance, J.Infrared, Millim. Terahertz Waves 31.4 (2010) 441–454.
[8] Hussein A. Abdulnabi, Refat T. Hussein, Raad S. Fyath, 0.1–10 Thz Single Port LogPeriodic Antenna Design Based on Hilbert Graphene Artificial Magnetic Conductor,(2006).

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 7.542 |

|| Volume 9, Issue 6, June 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0906222 |

[9] Alharbi, Khalid Hamed, et al., Diced and grounded broadband bow-tie antenna withtuning stub for resonant tunnelling diode terahertz oscillators, IET Microw.,Antennas Propag. 11.3 (2016) 310–316.
[10] Bassam Khamaisi, Samuel Jameson, Eran Socher, A 210–227 GHz transmitter withintegrated on-chip antenna in 90 nm CMOS technology, IEEE Trans. Terahertz Sci.Technol. 3.2 (2013) 141–150.
[11] Ke Wu, et al., Substrate-integrated millimeter-wave and terahertz antenna technology,Proc. IEEE 100.7 (2012) 2219–2232.
[12] E. Yablonovitch, Inhibited spontaneous emission in solid statephysics and electronics, J. Phys. Rev. Lett. 58 (20) (1987)2059–2062.
[13] S. John, Strong localization of photon in certain disordereddielectric super lattice, J. Phys. Rev. Lett. 58 (23) (1987)2486–2489.
[14] R. Gonzalo, P. de Maagt, M. Sorolla, Enhanced patch-antenna per-formance by suppressing surface waves using photonic-bandgapsubstrates, IEEE Trans. Microw. Theor. Tech. 47 (11) (November1999) 2131–2138.
[15] W.L. Stutzman, G.A. Thiele, Antenna Theory and Design, 2nded., Wiley, New York, 1998.
[16] C.A. Balanis, Antenna Theory, 2nd ed., John Wiley & Sons, Inc.,New York, 1997